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Report No. E6000-15
Quarterly Report No. 5

INVESTIGATION OF SLIP RING ASSEMBLIES

George C. Marshall Space Flight Center
Huntsville, Alabama

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I. INTRODUCTION

This is the fifth quarterly progress report on IITRI Project E6000, "Investigation of Slip-Ring Assemblies." This report summarizes the activities during the period 15 April 1964 to 5 August 1964 and is the first quarterly report on the twelve month continuation authorized by Modification No. 4 of Contract No. NAS8-5251. The objective of the twelve month continuation is to analyze the wear debris that is obtained during run-in of capsules, and to verify the vibration, threshold and repeatability effects that were demonstrated during the original program. Subsequent tasks of the extension will be devoted to study of vacuum operation of slip-ring assemblies.

During the period reported herein, preliminary analyses of wear debris deposits were conducted, and the basic noise characteristics demonstrated during the initial contract period were verified with commercial slip-ring assemblies. In addition, studies were initiated of precious metal hardening agents for gold plating baths, and of other basic noise parameters.

II. ANALYSIS OF WEAR DEBRIS DEPOSITS

Extended operation of presently designed miniature slip-ring capsules is not possible because of the high noise levels that result from accumulation of wear debris deposits during long-term operation. A study has been initiated to identify the chemical and metallurgical nature of the debris deposits so that its sources can be determined and corrective measures can be specified.

Capsule C1-28, a capsule containing soft gold rings which had accumulated 40.6 hours of run-in during the initial program, was reconditioned and subjected to a second run-in process. Incidental to the wear products run, characteristic noise and drag data was obtained with respect to run time and direction of rotation. The reconditioned capsule was selected primarily to establish whether the accumulation of debris was a one-time or continuous process.

After 34 hours of run-in at 200 rpm with the reconditioned capsule (redesignated as Capsule 1-28-2), excessive noise levels were obtained, and the test was terminated. Disassembly of the capsule revealed a relative large amount of debris, thus indicating that accumulation is a continuous process.

The wear debris deposits were extracted with carbon disulfide and the residue taken up in aqua regia and ashed on the carbon electrode for emission analysis. Approximately 0.1 milligram of the sample was present. The strongest lines from this sample were due to gold and calcium; weaker lines were due to aluminum, magnesium and iron.

To establish probable sources of the wear debris deposits, a sample of the P-38 oil used for bearing lubrication was ashed and then analyzed by the emission spectrograph. The strongest lines showed the presence of barium, calcium, strontium and magnesium. Aluminum and iron were present also but were much weaker.

Since the ring and brushes are made of gold, its presence in the deposits is expected. The presence of calcium, aluminum, magnesium and iron in the slip-ring deposits may be explained by their presence in the oil as established by the analysis of the ash from the oil. This is based on the assumption that the oil from the bearings is contributing to the deposits. At the present time, this assumption is not fully justified since the presence of barium and strontium should also then be expected. Because of this inconsistency, further testing of debris samples is required to obtain conclusive evidence on the nature of the deposits and the sources of the contamination.

In one additional test, the carbon disulfide extract was evaporated to about 0.2 ml and then injected into a gas chromatograph operated at 300° C, but no evidence of any organics or oil was obtained. Further work on this extraction technique and analysis will be conducted to establish the presence of non-metallic constituents.

The debris obtained from a capsule having no previous run-in will be analyzed and the results compared with those obtained for Capsule 1-28-2. For this purpose, Capsule 2-29 was assembled with soft gold rings, and run-in at 200 rpm was initiated. After 16 1/2 hours, the drag-torque of the capsule became so high that the drive motor stalled, and the capsule was therefore disassembled. It was found that the front bearing became misaligned due to wear of the rotor shaft. The noise level before failure was still very low and this was substantiated by the insignificant amount of debris that was present in the capsule. The rotor frame of Capsule 2 was remachined and refitted with a new front bearing. The capsule was then re-assembled with Ring 33, a soft gold ring having two 90° and two 80° grooves, and run-in was initiated to obtain further debris samples. After approximately 80 hours of run-in at 200 rpm, the noise level is still quite low, and therefore, further run-in will be conducted to insure a sufficient quantity of wear debris.

III. VERIFICATION OF VIBRATION, THRESHOLD, AND REPEATIBILITY EFFECTS WITH COMMERCIAL 80 RING CAPSULES

To confirm that noise characteristics obtained with experimental capsules during the original program are representative of general slip-ring performance, two commercial ST-124 Slip-Ring Assemblies were subjected to laboratory evaluation using the same instrumentation, apparatus, and techniques that were utilized for evaluation of experimental capsules. The torsional drive apparatus was modified to incorporate an aluminum reel between the inertial cylinder and the capsule rotor upon which the unused rotor leads were wound during oscillation and continuous rotation tests. Adjustment of the driving forces was also required to overcome the increased drag-torque of a commercial assembly.

The results of noise measurements with the two commercial capsules are presented in Table 1. As indicated, the noise levels are considerably below the accepted level of 10 microvolts per milliampere, and the fact that low noise levels can be obtained with commercial assemblies is attributed to the low vibration method used for driving the capsule.

Oscillation tests were performed with Commercial Assembly B to determine whether the threshold effect is generally applicable. Fig. 1 is

TABLE 1

NOISE MEASUREMENTS - COMMERCIAL ASSEMBLIES

	Threshold Noise at 25 ma - 2 rings	
	Oscillation	Continuous Rotation
Assembly A	26 μv, ptp	- - -
Assembly B	34 μv, ptp	34 μv, ptp

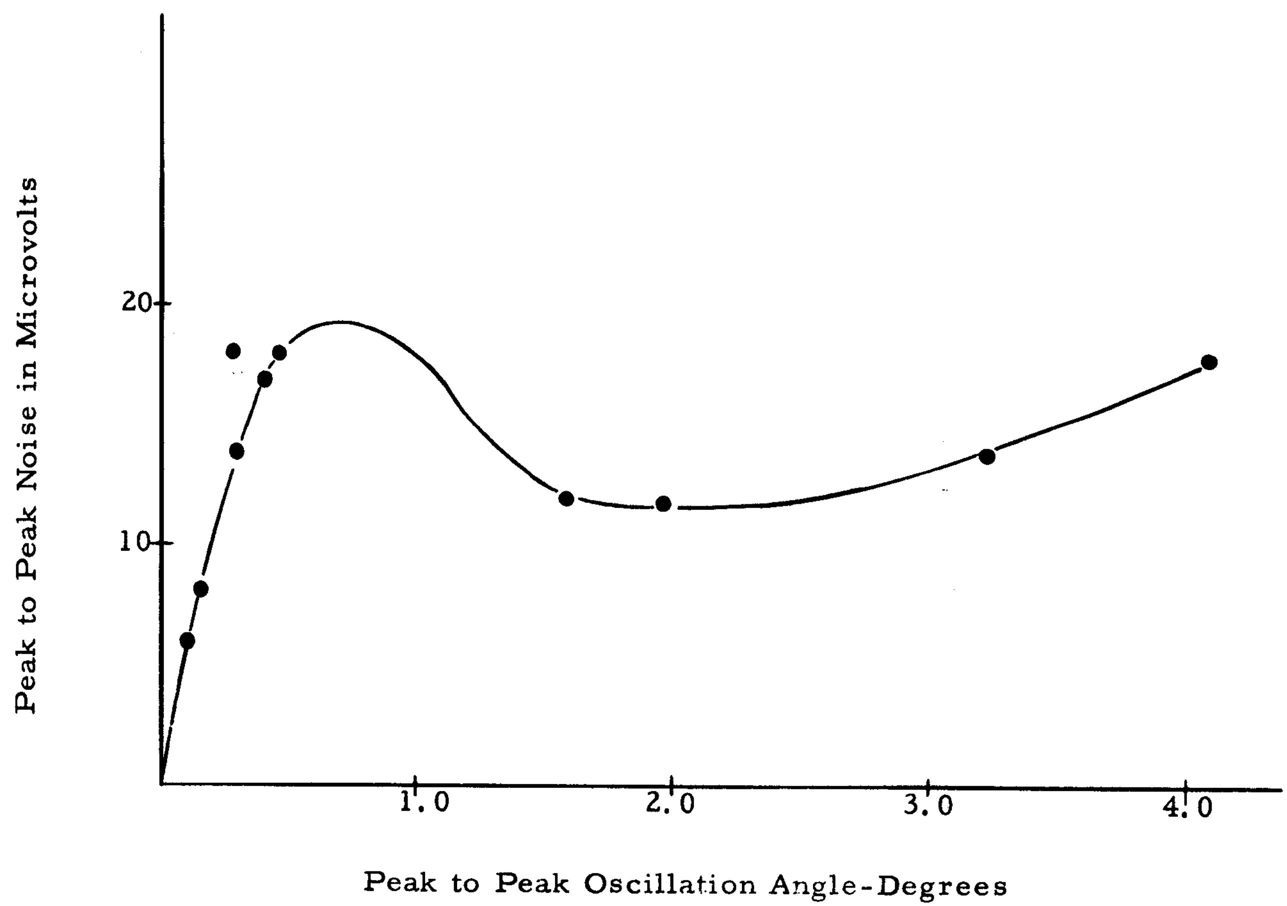

FIG. 1 - THRESHOLD EFFECT
COMMERCIAL CAPSULE B

a plot of peak to peak noise at 25 ma versus the peak to peak angular amplitude of oscillation at 10 cps. The relationship obtained is practically identical to that obtained for the experimental soft gold rings, and indicates that commercial capsules do exhibit the threshold noise effect.

The noise waveforms for commercial capsules during continuous rotation exhibit the same degree of repeatibility that was demonstrated by experimental capsules. Fig. 2 is an oscillogram of noise during rotation at 20 rpm. The upper of each pair of traces is the photo cell output produced by a mask attached to the rotor having 16 equally spaced holes around its circumference. One of the holes was masked and the hole adjacent was half-covered so that position and direction of rotation could be established by the absence of a light pulse, preceded or followed by a pulse of reduced amplititude. An example of noise repeatibility is the noise spike which occurs regularly at the position of the absent light pulse. The regularity of noise waveforms is attributed to the dependence of noise on localized surface imperfections.

The commercial capsules were also found to exhibit an "end oscillation" effect similar to that demonstrated by the experimental capsules. Because of the increased drag-torque of an 80 circuit capsule, the end oscillation motion attenuated quite rapidly. However, when external weights were added to the system to increase its moment of inertia, slowly decaying end oscillations were obtained. These oscillations are probably due to energy which is stored in the deflected brushes of the system.

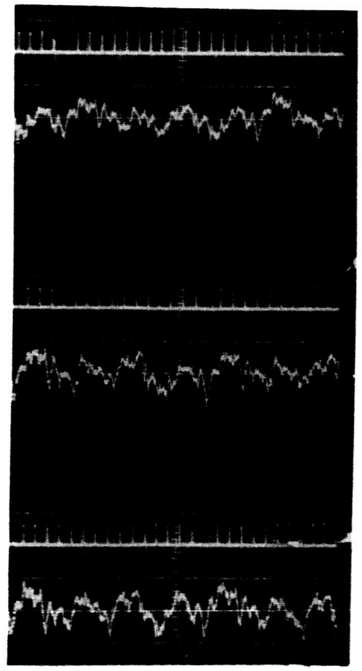

FIG. 2 - NOISE WAVEFORMS DURING ROTATION AT 200 RPM

COMMERCIAL CAPSULE B

IV. BASIC NOISE CHARACTERISTICS

In the continuing investigation of basic noise parameters, noise measurements for both the oscillatory and continuous modes were made with Capsule C1-28-3, a capsule containing soft gold rings and brushes having only one wiper arm. Several important differences in noise characteristics were noted, particularly during the oscillatory mode. With oscillation, a clipped noise waveform was obtained with large spikes occurring at times when the rotor started motion in a direction which placed the wiper arm in compression. When the travel was in a direction which placed the wiper in tension, very low noise levels were obtained.

To permit realistic comparison with the conventional brush systems, noise measurements with the single wiper system were made with a brush current of 12.5 ma. In the oscillatory mode, peak to peak noise of 75 μv was obtained with Capsule C1-28-3. In the continuous rotation tests, peak to peak noise levels of approximately 50 μv were obtained with rotation in either direction. Excellent repeatibility of noise waveforms was obtained for rotation in similar directions. Table 2 is a brief comparison of the basic characteristics of the single wiper and conventional double wiper systems.

In the original program, a simplified theoretical analysis suggested that there may be some advantage in using 80° grooves in place of 90° grooves. As discussed earlier in the report, Capsule 2-33 was assembled with a soft gold ring cylinder having two 80° grooves and two 90° grooves. A run-in test was initiated to permit performance comparisons and also to acquire an additional sample of wear debris. Initially, the 80° grooves had a threshold noise of 40 μv, ptp, as compared to 35 μv for the 90° grooves.

TABLE 2

SINGLE AND DOUBLE WIPER BRUSH SYSTEMS

	Single Wiper Capsule C1-28-3 (Noise at 12.5 ma)	Double Wiper Capsule C1-1B (Noise at 25 ma)
Average Brush Force-Grams	2.51	2.59
Average Drag Torque-Gram-Cm	2.74	5.12
Average Resistance-Two-ring Ckt-Ohms	0.577	0.546
Threshold Peak to Peak Noise - Oscillation - μv	75	34.8
Threshold Peak to Peak Noise - Continuous Rotation - μv	50	34.8

The higher value may be due to the fact that the 80° grooves were machined with a carbide tool while the 90° grooves were machined with a diamond tool.

After approximately 80 hours of run-in, both sets of grooves are still low-noise, but the 80° grooves demonstrated a slightly lower noise level than the 90° grooves. If this trend continues during further run-in, additional investigation of this concept is believed to be warranted.

V. PRECIOUS METAL HARDENING AGENTS

The results of the study of precious metal hardening agents carried out during the first year's effort were inconclusive, primarily because of the difficulties that were encountered in obtaining reference plating samples from the bath selected as the vehicle for the additions (Overage Bath). Because of the potential merit of this concept, it was decided that further exploratory work would be conducted using the Orotemp 24k bath as the basic bath for additions.

To obtain references for comparison purposes, five ring cylinders were plated from the standard Orotemp 24k bath. The specimens were metallurgically polished, and micro-hardness measurements were made. During the future period, samples will be plated from baths containing various combinations of precious metal hardening agents, and their hardness will be compared to that of the reference samples.

VI. SUMMARY

The preliminary analysis of wear debris performed thus far has indicated that metallic constituents other than the expected gold are present. One probable source is the P-38 oil used for bearing lubrication; however, further analysis and refinement of technique is required to obtain conclusive evidence.

Laboratory evaluation has indicated that commercial 80 circuit slip-ring assemblies exhibit the same vibration, threshold and repeatibility effects that were demonstrated by experimental capsules. End oscillation effects were also observed.

A run-in test presently in progress has indicated that 80° grooves may possess improved noise characteristics over the standard 90° grooves.

VII. FUTURE ACTIVITIES

During the next quarterly period of this program, the following activities will be performed.

A. Additional samples of wear debris will be collected and analyzed. The analysis techniques will be refined to establish the presence of non-metallic components. Debris samples from commercial capsules will also be obtained.

B. The study of precious metal hardening agents will be continued.

C. Further studies of basic noise parameters will be carried out.

VIII. PERSONNEL

IITRI staff members who have participated in the activities described in this report are O. M. Kuritza, W.H. Graft, R.E. Putscher, and D. E. Richardson.

Respectfully submitted,
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